# Validation of Atmospheric Forcing Data for PIPS 3

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## LONG-TERM GOAL

Our goal is to provide a thorough evaluation of atmospheric forcing fields to be used in the development and operational implementation of the planned upgrade of the Polar Ice Prediction System (PIPS). Our research will provide information on the temporal and spatial distribution of errors in the Navy Operational Global Atmospheric Prediction System (NOGAPS) atmospheric forcing fields for the PIPS domain; an assessment of the impact of these errors on the PIPS forecasts; and suggest ways to improve forcing fields or mitigate their impact on PIPS forecasts.

## OBJECTIVES

We will evaluate NOGAPS atmospheric forcing variables, surface radiative fluxes, surface winds, and precipitation estimates to be used in the development and operation of the PIPS 3.0 model. We will answer the following questions: How large are the errors? Where and when do they occur? What is their significance in the context of PIPS forecast variables such as ice thickness, ice extent, ice motion and deformation? What are likely sources of these errors? How do these errors rank in comparison with other forcing data sets? What can be done to eliminate them or to mitigate their effect? The proposed work will provide answers to these questions.

## APPROACH

Our approach to validating the atmospheric forcing data used for the PIPS model includes three separate components.

- Comparison of NOGAPS model output with data from field experiments such as SHEBA.
- Comparison of NOGAPS fields with fields from other data sets such as radiative fluxes calculated from TIROS-N Vertical Sounder (TOVS), International Artic Buoy Program (IABP) surface temperatures and geostrophic winds, as well as corresponding field from the European Center for Medium range Weather Forecasting (ECMWF) and National Center for Environmental Prediction (NCEP) analysis centers.
- Assess the impact of determined errors on relevant ice model output variables such as ice concentration and ice extent.

# Report Documentation Page

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14. ABSTRACT

**Our goal is to provide a thorough evaluation of atmospheric forcing fields to be used in the development and operational implementation of the planned upgrade of the Polar Ice Prediction System (PIPS). Our research will provide information on the temporal and spatial distribution of errors in the Navy Operational Global Atmospheric Prediction System (NOGAPS) atmospheric forcing fields for the PIPS domain; an assessment of the impact of these errors on the PIPS forecasts; and suggest ways to improve forcing fields or mitigate their impact on PIPS forecasts.**

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## WORK COMPLETED

- To date we have conducted a comparison of NOGAPS variables with surface measurements at the SHEBA camp.
- In order to evaluate NOGAPS field beyond a single point (SHEBA) we have compiled a "Reference Radiative Flux" data set of downwelling short and long-wave fluxes. This reference data is based on satellite retrieved cloud fractions (TOVS), and IABP buoy temperatures. We have validated this reference data set and used it to evaluate the NOGAPS forcing and to conduct sensitivity studies with a coupled ice-ocean model.
- We have conducted a series of sensitivity studies to determine the potential impact of errors identified in the NOGAPS forcing fields on model output parameters. Sensitivity studies with respect to the downwelling long and short-wave fluxes were conducted.
- Because of the large errors found in the NOGAPS surface temperature structure we were concerned about the quality of surface stresses provided by the NOGAPS model. We therefore conducted model runs using the NOGAPS wind stress and compared them to equivalent runs in which surface stress is parameterized from geostrophic wind.
- We expanded the evaluation period beyond SHEBA. NOGAPS model changes have apparently caused significant changes in the NOGAPS analysis for the Arctic just after the SHEBA period. An expansion of the analysis has therefore become necessary.
- We have compared NOGAPS analysis errors with errors present in comparable forecast models such as the ECMWF and National Center for Environmental Prediction (NCEP) reanalysis projects. This comparison provides a benchmark for the developers of NOGAPS.
- Using the reference data set of short-wave fluxes we investigated the variability in model output parameters due to the temporal variability in short-wave fluxes. We show that this variability over a period of 19-years is rather small. A well-tuned climatology of short-wave fluxes (such as the reference data set) may be more suitable for running the PIPS model.
- We have prepared a detailed report on the evaluation. This report will be circulated among PIPS implementation team members shortly.

## RESULTS

***Surface Temperature:*** Figure 1 shows a comparison of surface air temperatures from the NOGAPS model, the IABP and the NCEP reanalysis data for the period January 1997-June 2001. Plotted are the differences between the NOGAPS and IABP and NCEP and IABP fields averaged for the area north of 70°. There are several noteworthy conclusions that can be drawn from this analysis. Wintertime surface air temperatures in the NOGAPS analysis are too high in 1997 and the early part of 1998 by up to 9°K. Into the second part of 1998 and the winters of 1999 and 2000 surface air temperatures in the NOGAPS analysis is too low by about 2-3° K. A check of the change-log for the NOGAPS model indicate that there was an increase in the number of levels from 18 to 24 with the move from NOGAPS 3.4 to NOGAPS 4.0 in June of 1998. Because summer temperatures are in relatively good agreement before and after the change, it is possible that the reversal in the sign of NOGAPS errors is due to this

change in NOGAPS properties. An additional change in the cloud parameterization scheme in February of 2001 appears to not have impacted the differences significantly.

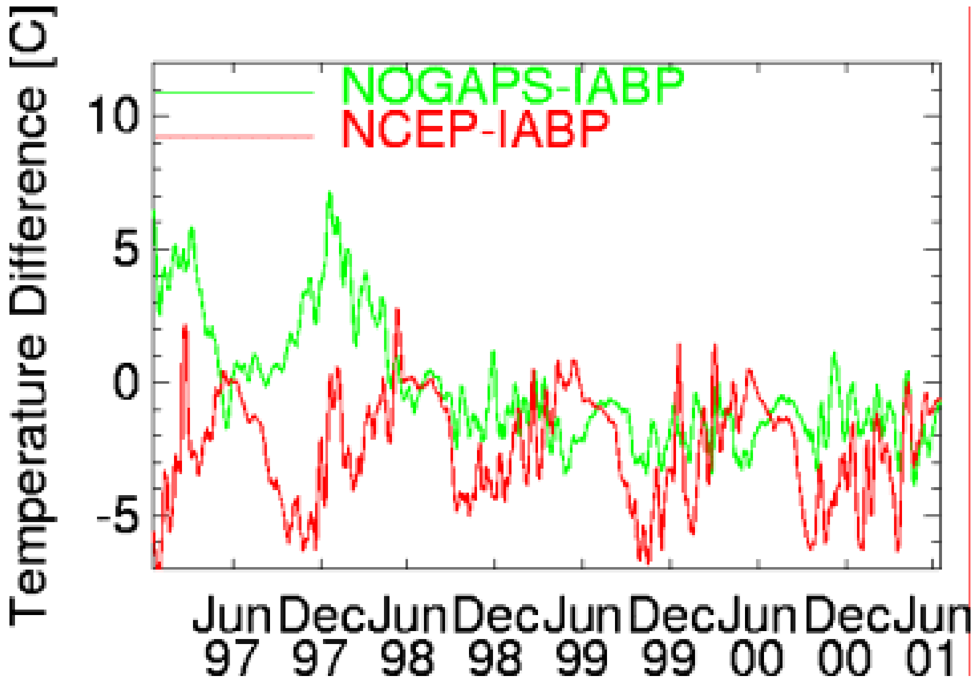



***Figure 1. Difference in surface air temperature between NOGAPS, NCEP and IABP data sets***

The comparison with NCEP forecasts shows that this model has errors similar in magnitude but with an opposite sign. From this analysis of surface temperatures averaged over the 70° domain it would appear that starting in the fall of 1998 NOGAPS temperature analyses are much improved. However, when comparing the spatial patterns of differences between the IABP and the NOGAPS analysis it becomes apparent that this is not the case. Figure 2 shows the February mean monthly differences between NOGAPS and IAPB surface temperatures for 1997 and 2001. NOGAPS temperatures in February 1997 exceed IABP surface temperatures by 4-16°K. In February 2001 NOGAPS temperatures over the western Arctic sector are up to 16°K below the IABP temperatures.
In the eastern part of the Arctic and over land areas, NOGAPS temperatures are generally higher than the IAPB temperatures. The pattern for Feb 2001 is representative for the winters of 1999 and 2000 as well.

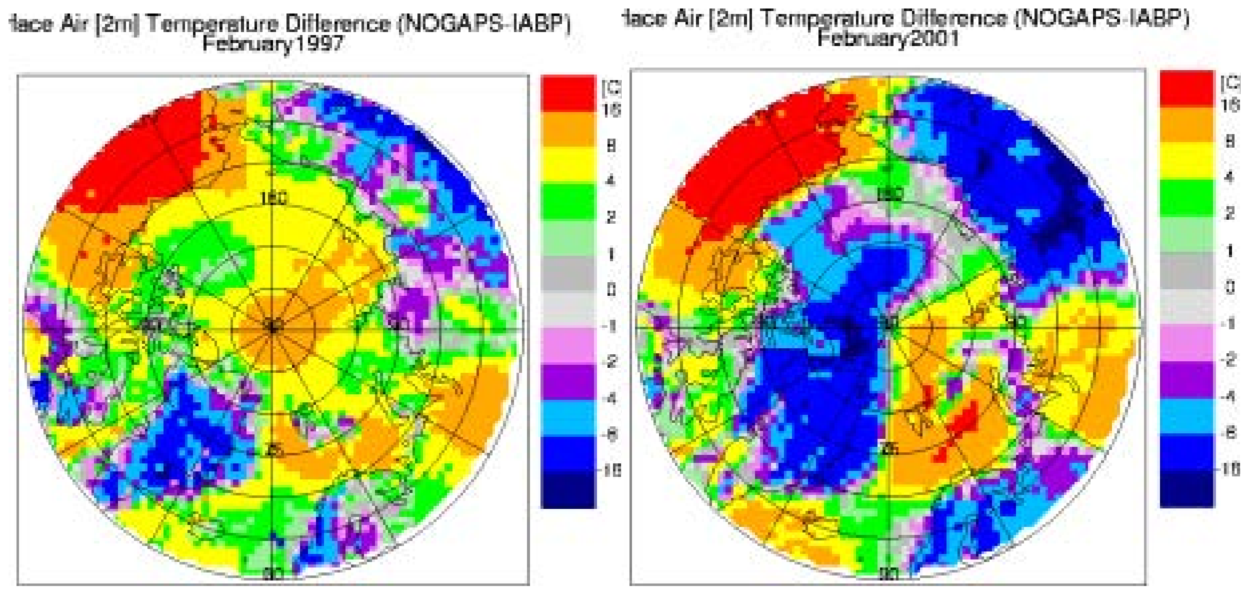
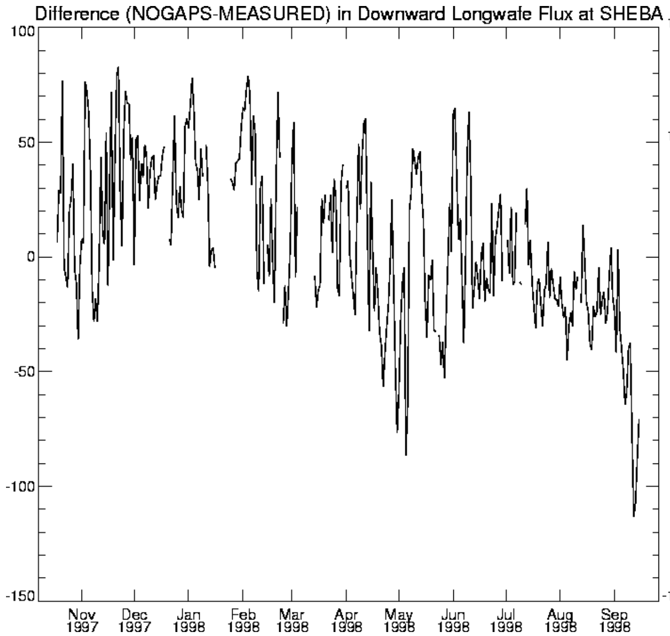
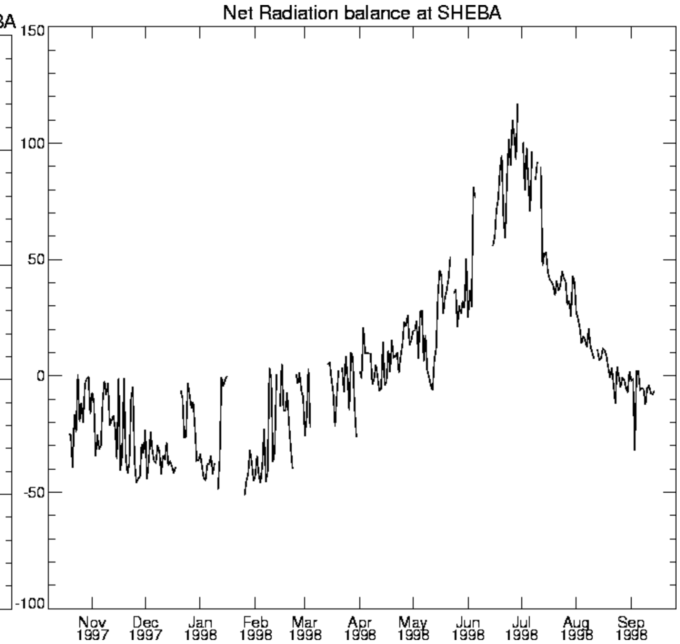



***Figure 2. Mean monthly difference of surface air temperature from the IABP and NOGAPS data sets (NOGAPS-IABP) for a) February 1997 and b) February 2001***

***Long-wave Fluxes****:* PIPS is driven with downwelling long-wave fluxes (DLF). Since these fluxes were, until recently, not available, DLF are calculated from NOGAPS net long-wave fluxes and NOGAPS surface temperatures. Fig 3a shows a comparison of DLF measured at SHEBA and from the NOGAPS. During summer NOGAPS DLF exceed SHEBA measurements by approximately 50 $Wm^{-2}$. Summer measurements are close to the NOGAPS analysis, though large differences exist for individual days. Toward the end of the SHEBA period (September 1998) NOGAPS fluxes drop well below SHEBA measurements by up to 100 $Wm^{-2}$. This is possibly an indication of the impact of the NOGAPS model change in June 1998 and the subsequent underestimation of surface temperatures starting in winter 1998 as noted above in the comparison of surface temperatures.




***Figures 3. Difference between measured and NOGAPS DLF at SHEBA (a) and total net radiation balance at SHEBA (b)***

The magnitude of the differences needs to be viewed in the context of the total radiation balance. Figure 3b. shows the total radiation balance measured at SHEBA. Except during the summer month, the total net radiation balance is quite small. NOGAPS analysis errors are much larger (up to 2500%) than the total net radiation balance. Since ice growth is very sensitive to the individual components to the energy balance, such a large error will undoubtedly affect the ice forecast provided by PIPS.

***Short-wave Fluxes:*** During summer, short-wave fluxes dominate the surface energy balance. Currently PIPS is driven by the net short-wave fluxes that are provided by the NOGAPS model. The reason for this is apparently historical because NOGAPS downwelling short-wave fluxes are not readily available. We therefore compare net short-wave fluxes (NSF) from SHEBA with those provided by the NOGAPS model. Figure 4 shows SHEBA measurements and NOGAPS analysis. NOGAPS NSF generally exceed measured fluxes except for July. The overestimation of NSF is particularly large in May. A comparison of figures 4 and 3b (total radiation balance) again shows that the differences between NOGAPS and SHEBA -a measure of the uncertainty in the NOGAPS analysis- are several times greater than the net radiation balance. This again indicates that the PIPS ice forecasts are likely to be severely impacted by the errors in NOGAPS radiative fluxes.

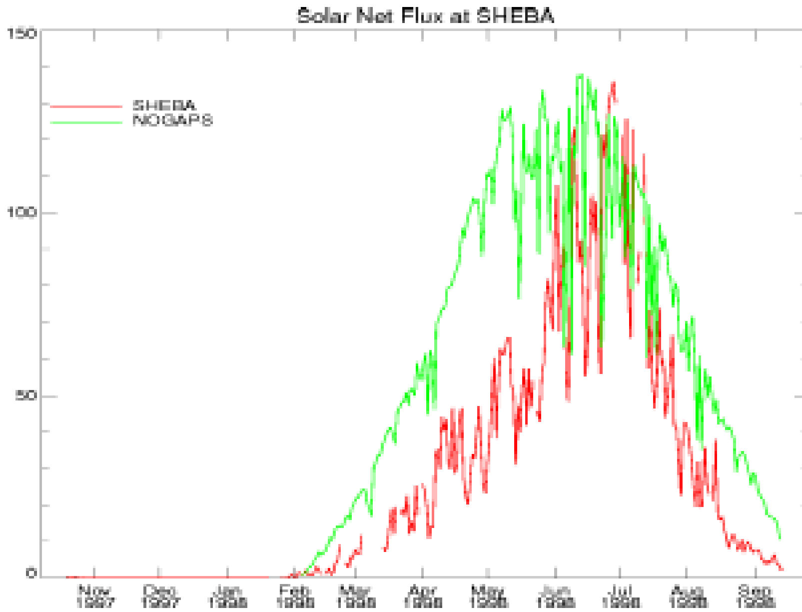



***Figure 4. Net short-wave fluxes from the NOGAPS model and those measured at SHEBA.***

***Model Results****:* Only a short summary of model results is possible here. A more detailed report is available from the Author. A comparison of sea ice thickness calculated with the NOGAPS short and long-wave fluxes with results using our reference data set shows that winter time ice thickness is lower by about 0.5-1 m, particularly in the western Arctic. Summer time ice thickness is lower by 1-2 m due to the excess in short-wave radiation. Our model results also show that the variability in ice parameters due to the variability in SW radiation is in the order of 10-15%. This relatively low variability when viewed in context of the large biases observed in the NOGAPS analysis suggests that the use of a well-tuned climatology of surface radiative fluxes would be a better strategy for running PIPS.

Comparison of ice-velocity model output with some 8,000 daily velocity observations from the IABP buoys shows that the sea-ice model performs better when driven with NOGAPS surface stresses than when driven with surface stresses calculated from geostrophic winds. Given the poor performance of NOGAPS in modeling the surface temperature, this result is somewhat surprising. A more detailed analysis of the spatial and temporal distribution of the velocity errors is pending.

## IMPACT/APPLICATION

The large wintertime temperature errors we found in the NOGAPS data are highly relevant to the further development of PIPS. Ice model results have demonstrated the large impact these errors have. NOGAPS developers need to renew their efforts to improve the model in the Arctic. PIPS IPT members are advised to adopt alternative strategies for driving PIPS.

## TRANSITIONS

As PIPS 3.0 is being implemented at Naval Research Laboratory (NRL), additional sensitivity runs will be conducted to determine the sensitivity of the final PIPS model to errors in radiative fluxes.

## RELATED PROJECTS

Tony Beasely,  formerly  at the National Ice has Center (NIC) completed a study of the causes of the forecast errors. This study needs to be expanded to identify the cause of the reversal of forecast errors in the fall of 1998.